

1994018767
N94-28240

1993 NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

510-61
197196
p. 39

COST BENEFITS OF ADVANCED SOFTWARE:
A REVIEW OF METHODOLOGY USED AT KENNEDY SPACE CENTER

PREPARED BY:

Dr. Prafulla N. Joglekar

ACADEMIC RANK:

Professor

UNIVERSITY AND DEPARTMENT:

La Salle University
Management Department

NASA/KSC

DIVISION:

Shuttle Project Engineering

BRANCH:

Process Integration

NASA COLLEAGUE:

Arthur E. Beller

DATE:

August 6, 1993

CONTRACT NUMBER:

University of Central Florida
NASA-NGT-60002 Supplement: 11

Acknowledgments

I am thankful to the NASA/ASEE fellowship program for this research opportunity. It has been exciting to witness space exploration from this proximity. It was intellectually very satisfying to be exposed to research in so many different disciplines related to NASA's mission. At the same time, it was very interesting to observe the management of the operations involved in getting an Orbiter ready for the next launch. It was most fascinating to study the development of future information systems to support that management.

I feel privileged to be able to propose a methodology for systematic and rational choices among information systems investment alternatives. Although I was not successful in demonstrating the actual use of my methodology, I have come to realize that, given the existence of the vicious circle I have discovered in this study, that was an unrealistically ambitious goal. On the other hand, I believe that I have enriched my own understanding of the methodology and designed a process for its implementation that is superior to any other process I have seen in the CBA literature.

I appreciate the generosity, and candidness of the many NASA and Lockheed employees I interviewed this summer. I have very freely used many of their ideas in this report without explicitly crediting them for the same. But I do want to thank them for the same. Special thanks are due to the authors of the four studies I was allowed to use as attachments to my report.

Ray Hosler (UCF), and **Kari Stiles** (UCF) provided valuable and very effective administrative support, as well as educational and entertainment opportunities. **Gene Thurston's** (TV-PEO-1) constant encouragement and guidance allowed me to overcome the occasional frustrations I encountered. Finally, this summer could not have been as enjoyable as it has been, without the help of **Art Beller** (TV-PEO-12) who is an outstanding mentor, thinker, facilitator, and by now, a close friend. I express my heartfelt gratitude to each one of these special individuals.

COST-BENEFITS OF ADVANCED SOFTWARE: A REVIEW OF METHODOLOGY USED AT KSC

**By
Prafulla Joglekar**

Abstract

To assist rational investments in advanced software, a formal, explicit, and multi-perspective cost-benefit analysis methodology is proposed. The methodology can be implemented through a six-stage process which is described and explained. The current practice of cost-benefit analysis at the Kennedy Space Center is reviewed in the light of this methodology. The review finds that there is a vicious circle operating. Unsound methods lead to unreliable cost-benefit estimates. Unreliable estimates convince management that cost-benefit studies should not be taken seriously. Then, given external demands for cost-benefit estimates, management encourages software engineers to somehow come up with the numbers for their projects. Lacking the expertise needed to do a proper study, courageous software engineers with vested interests use ad hoc and unsound methods to generate some estimates. In turn, these estimates are unreliable, and the vicious circle continues. The proposed methodology should help Kennedy Space Center to break out of this vicious circle.

COST-BENEFITS OF ADVANCED SOFTWARE: A REVIEW OF METHODOLOGY USED AT KSC

**By
Prafulla Joglekar**

Executive Summary

Advanced software (ASW) investment decisions are multi-stage, varied, complex, risky, and controversial. Therefore, we need a systematic methodology to assist rational ASW investment decisions. I propose a formal, explicit, and multi-perspective cost-benefit analysis (CBA) methodology for this purpose. I outline a number of rich concepts and principles of this methodology, and recommend a six-stage process for its implementation. In the light of this methodology, my review of the current practice of CBAs at KSC finds that the practice is seriously deficient.

The basic cause underlying these deficiencies is that we are caught in a vicious circle described by the following paragraph:

At present, CBA studies fail to capture all the relevant concerns. They measure only selected costs and benefits using questionable assumptions and unsound methods. As a result, the estimated costs and benefits are highly unreliable. Consequently, management looks at CBAs not as decision-making tools, but as mere exercises in generating numbers for external justification of decisions already made. Thus, management does not take CBA studies seriously, and simply leaves the conduct of CBAs up to the initiative of the software engineers involved in specific projects, without any provision for additional resources and expertise needed for these studies. Lacking resources, and the necessary expertise in economic analysis, but with vested interests in justifying their projects, courageous software engineers use creative, but ad hoc and unsound methods to conduct their CBAs. The resulting cost-benefit estimates are highly unreliable, and certainly not worthy of use in any rational decision-making. Thus, management's view that CBAs are to be used merely as exercises in generating numbers for external justification is reinforced, and so on. The vicious circle continues!

I recommend that at KSC, we should try urgently to break out of this vicious circle. The methodology I have proposed provides one exit point to break out of this circle. The other exit point is a change in management's perception of what a good methodology can do, and its willingness to provide adequate resources and appropriate expertise to the conduct of CBAs.

Table of Contents

| <u>Section</u> | <u>Title</u> | <u>Page</u> |
|----------------|---|-------------|
| 1. | INTRODUCTION | 1 |
| 2. | THE PROPOSED METHODOLOGY | 4 |
| 2.1 | Richness of the methodology | 4 |
| 2.2 | A Clarification of Some Common Misperceptions | 5 |
| 2.3 | A Process for Implementation | 6 |
| 2.4 | Implementation Requirements and Advantages | 11 |
| 3. | A REVIEW OF THE CURRENT PRACTICE AT KSC | 12 |
| 3.1 | The Vicious Circle | 13 |
| 4. | CONCLUSION AND RECOMMENDATIONS | 16 |
| | REFERENCES | 17 |
| ATTACHMENT A | EXCERPTS FROM A CBA OF SCAN REPLATFORMING | A-1 |
| ATTACHMENT B | CBA FOR THE DEPLOYMENT OF KATE | B-1 |
| ATTACHMENT C | EXCERPTS FROM A CBA OF GPSS | C-1 |
| ATTACHMENT D | RUBICON COST ANALYSIS STUDY | D-1 |

Abbreviations and Acronyms List

| | |
|---------|---|
| ASW | Advanced Software |
| CBA | Cost Benefit Analysis |
| CEA | Cost Effectiveness Analysis |
| CUA | Cost Utility Analysis |
| DTA | Decision Tree Analysis |
| GPSS | Ground Processing Scheduling System |
| G&A | General and Administrative overhead costs |
| KATE | Knowledge-based Autonomous Test Engineer |
| KSC | Kennedy Space Center |
| LRU | Link Replaceable Unit |
| RP | Rapid Prototyping |
| RUBICON | Reasoning Based on Intelligent Computer Operations and Networking |
| SCAN | Shuttle Connector Analysis Network |
| TA | Technology Assessment |

COST - BENEFITS OF ADVANCED SOFTWARE: A REVIEW OF METHODOLOGY USED AT KSC

1. Introduction

Advanced software (ASW) projects are exciting. They keep us at the cutting-edge of technology; they help us develop and challenge the best minds in software development; they promise to capture the knowledge and expertise of the brightest and the most experienced personnel in the space program; they promise to minimize the chance of a human error while maximizing the chance of rapid trouble shooting in a launch count-down; and in general, they have the potential to help improve the effectiveness and efficiency of the operations at Kennedy Space Center (KSC). With the national focus on US competitiveness, we are also looking forward to ASW projects that promise commercial spin-offs.

As exciting as these promised benefits are, software development alone does not ensure actual realization of those benefits. Often many other necessary conditions must be obtained. For example, software such as Knowledge-based Autonomous Test Engineer (KATE) and Reasoning Based on Intelligent Computer Operations and Networking (RUBICON) will not enable us to actually reduce the manpower at the Firing Room consoles until management is willing to deviate from the traditions and practices that have clearly worked in the past, but that may be inferior and costly in the future compared to the use of these ASW.

On the other hand, advanced software development is not necessary to obtain certain improvements in operations efficiency. One well-known problem of today's computer systems is that their true potential is seriously under-utilized. For example, we are nowhere near realizing the reductions in hard-copy costs that are possible with the electronic communication capabilities already in place. Thus, detractors of ASW often suggest that what we need is not more investment in ASW, but more investment in the training and in the management of a change in people's attitudes and habits necessary for a fuller exploitation of the existing technology. Of course, proponents of ASW counter that exploiting even a small fraction of the potentially huge benefits of an ASW project may be well worth the costs of its development. Clearly, we need to identify the optimal mix of resources to spend on ensuring fuller use of existing technology and on developing new ASW.

In addition, there are a variety of interesting and challenging issues to resolve in ASW investment decisions. Given many ideas for ASW projects and limited resources at hand, we must decide which ideas to pursue and at what level of funding. By their very nature, ASW projects take many years to complete and carry the risks of technical, schedule, or operational failure. Thus, investment decisions pertaining to an ASW project are not simple one-shot, yes-or-no type decisions, but multi-stage decisions requiring a reassessment and redesign of the project at various stages in its life cycle. Below are a

few examples of the many interesting and challenging issues one has to deal with when making ASW investment decisions.

Some projects, such as the replatforming of the Shuttle Connector Analysis Network (SCAN), seem unavoidable given the obsolescence of the current platform. Yet, replatforming opens several possibilities for enhancements to current SCAN capabilities (e.g., LRU trace-through, Automated retest, Wire trace diagnostics, etc.), and total project costs depend upon the enhancements we decide to seek. We would be foolish not to exploit some of these opportunities for enhancements. However, the larger the set of enhancements we seek, the greater would be the project complexity and the consequent risk of failure. Thus, the real issue to be decided here seems to be what specific enhancements to seek and what not to.

Some projects, such as the Ground Processing Scheduling System (GPSS), seem to deserve continued funding on the basis of their past and measurable successes. However, the issue here may be who should fund it from this point on, and at what level? If GPSS's benefits are clearly demonstrable and the costs of its further development will be lower than its future benefits, is it time to spin it off as a commercial venture? Under this approach, a private firm will have to fund GPSS's further development and share in the rewards of its future success. Thus, a larger portion of Code C budget may be available to fund other ASW projects which may be too risky for a private (and risk-averse) entrepreneur but quite acceptable to a (risk-neutral) government. On the other hand, because of the many complicated legal and political issues involved, attempts to commercialize GPSS too soon could actually slow down its development and implementation.

Other ASW projects such as KATE, and RUBICON seem to deserve continued funding because they are based on truly visionary technologies. The issue here is whether these ASW projects represent a situation of "a solution looking for a problem to solve," and whether given our desire for being at the cutting-edge of technology, funding of visionary technologies is justified in and for itself.

Another issue pertaining to KATE and RUBICON seems to be the threshold level of funding needed to keep these projects at a reasonably productive pace. For some projects, no funding at all may be better than some funding below the threshold level. One concern is that with the speed at which some ASW projects are proceeding, there may be cheaper and better commercial products on the market long before our development is complete. Considering that possibility, the question is: Are we simply providing taxpayer-funded software development experience to the contractor?

When funding an ASW project (See Attachment A), we seem to budget for the time software engineers would spend on that project. In reality, the project uses many other resources in the organization. Computer hardware, and office supplies are the obvious examples of these. In addition, there are many *hidden* costs (hidden until we recognize them). For example, to the extent that ASW projects attempt to capture corporate knowledge and expertise, they require substantial time and cooperation from

various experts. Unless these experts' time is explicitly budgeted for the ASW project, project schedule and success may depend on the goodwill of the experts, and may even risk neglect of the experts' normal duties which may be launch-critical today. Unless all relevant costs of an ASW project are uncovered, added-up, and compared with the project's likely benefits, one does not know whether that ASW development would be a wise idea.

At the same time, it should be realized that if the experts are not convinced of the value of the project, or think that their jobs will be at risk once their expertise is captured, software engineers will not succeed in capturing their expertise. In other words, successful implementation of an ASW project often requires that each one of the many stakeholders of the project should find it cost-beneficial from his/her own perspective.

In short, ASW investment decisions are multi-stage, varied, complex, and risky, and their success depends on the cooperation of multiple stakeholders. It is no surprise that while there are a few success stories, there are many more instances of project failures, long delays, and wasted resources. Thus, most ASW investment decisions seem to be controversial. It is therefore imperative that we develop a systematic methodology to assist rational ASW investment decisions.

In Section 2, I propose a cost-benefit analysis (CBA) methodology to assist these decisions. I had hoped to demonstrate the use of this methodology in a couple of actual decision situations. Unfortunately, at KSC the concept of what a CBA methodology can do, and where to apply it, seems to be very different than mine. At KSC, CBAs are used to justify past decisions, or our preferred choices, to some external constituency. CBAs are not seen as an assistance to decision-making. Indeed, ASW projects that are facing serious decision points seem to avoid a systematic CBA. As a result, I did not really get a chance to demonstrate the use of my methodology. On the other hand, as is clear from the discussion in Section 2, I did have the opportunity to study several instances of the current practice of CBA at KSC. Attachments A through D present the relevant excerpts from the CBAs I studied. In section 3, I review the current practice as a whole and contrast it with my methodology. Section 4 provides my conclusions and recommendations.

2. The Proposed Methodology

Rational decision-makers always assess the costs, benefits, and risks of the alternative choices they have. However, this assessment is often informal, implicit, and only from a single (the decision-maker's) point of view. I recommend that at KSC the assessment of ASW investment alternatives be **formal, explicit, and multi-perspective**. Organizational decision-makers clearly recognize the need for a formal process of assessment. An explicit assessment forces us to articulate all underlying assumptions and verify their validity. An explicit process is also easier to study, improve over time, and pass on from one generation of decision-makers to the next. Many researchers suggest that a cost-benefit assessment be "objective." I believe that costs and benefits of an ASW lie in the "eye of the beholder." In other words, assessments, by their very nature, depend upon one's point of view, and hence are subjective. Instead of attempting to avoid this subjectivity, I recommend that the assessment be from the point of view of each one of the major stakeholders of an ASW investment. As I have suggested before, such a multi-perspective assessment improves our chances of obtaining full cooperation from all the stakeholders, and hence the chances of project success.

Rational decisions based on such a formal, explicit (therefore well documented), and multi-perspective assessment need no further efforts to justify them to our superiors or to the general public.

2.1 Richness of the Methodology

Formal CBAs have been done for over ninety years now, ever since the 1902 Harbor Act required that Army Corps of Engineers could build only those water projects that could be shown to generate more money than they consumed. Given the language of the Harbor Act, the foci of early CBA were on

- (i) *justifying* a decision already made, and
- (ii) quantifying all costs and benefits in *dollar terms*.

In many organizations, these foci continue to prevail even today. However, over the years, as CBAs are done in a wide variety of organizations analyzing a wide variety of decision situations, the CBA methodology has evolved considerably. In a previous publication [1], I have reviewed this evolution, and clarified a number of common misunderstandings about what a CBA methodology is, and is not.

Briefly, by now, we recognize that although a CBA can be used to justify a decision already made, *its most cost-effective use lies in arriving at the right decision*. We know that not all cost and benefits can be measured in dollar terms, if they can be measured at all. We have developed a variety of techniques such as cost-effectiveness analysis (CEA), cost-utility analysis (CUA), and technology assessment (TA) to accommodate variables that defy measurement and valuation in dollar terms. More importantly, we recognize that rational decisions can be made without forcing a quantification of the non-quantifiable, or a prediction of the unpredictable. I see these insights and techniques as an integral part of what I call "the CBA methodology."

The most fundamental principle of the CBA methodology is to account for (not necessarily quantify) **all incremental costs and benefits** resulting from a decision alternative. To enable us to do this task properly, the methodology provides a number of rich concepts and principles. For example, it describes the many different types of costs and benefits we may encounter, including: direct and indirect; tangible and intangible; fixed and variable; controllable and non-controllable; one-time and recurrent; etc. The methodology emphasizes the need to account for the *opportunity cost* of an action. The principle is to count the net benefits we would have reaped had we taken the best alternative action instead of a given action, as a cost of the given action.

The methodology tells us to pay attention to the cause-effect as well as the multi-producer-single-product relationships as may be present, and to attribute benefits and costs to the causes or the producers, as appropriate. It incorporates concepts and tools to adjust for the associated risks and uncertainties. In analyzing a multi-year stream of costs and benefits, the methodology provides us with techniques for converting these multi-year flows to comparable and consistent units, so that we do not "confuse apples for oranges". In short, the methodology is very rich and insightful.

2.2 A Clarification of Some Common Misperceptions

Unfortunately, in the information systems literature, some scholars have incorrectly equated CBA methodology with such financial techniques as internal rate of return or present value calculations. While accounting for the time value of money is an important principle of CBA methodology, the methodology is much broader in its scope than the narrow techniques it may use in specific analytical situations. I want to emphasize that I am recommending a **methodology**, not a single technique.

A methodology includes not only a toolkit, but also an understanding of the situations where each tool is most appropriate to use. Self-examination and improvement are integral parts of a methodology. Thus, answers to questions such as "Is cost-benefit analysis beneficial? Is cost-effectiveness analysis effective?" are legitimate parts of the methodology [2]. We recognize that some times, the benefits of conducting a formal and explicit CBA are not worth the time and costs required. The proposed methodology welcomes a formal, explicit, and rational decision not to pursue a CBA in such situations.

The methodology also requires that the scope and the level of detail of a CBA study be consistent with the magnitude of the likely costs of a wrong choice in an ASW investment decision, and with the time available for decision-making. A CBA study that costs \$10,000, when the largest possible difference between the net benefits of the best and the worst choice is only \$5,000, does not make any sense. Similarly, a study that takes a year to complete will not assist a decision that must be made within a month. Thus, in my view, a common fear, namely that a CBA will cost too much and take too long, is simply a misperception of the methodology.

One widely-held belief is that a CBA is useful only when a project is initially approved or disapproved, and it has no role to play in subsequent decisions about annual funding levels, etc., particularly so, if an original CBA was not conducted at the time of initial project approval. Once the methodology proposed here is in place, there will be no reason to assume that a CBA with properly defined scope and level of detail cannot assist the current year's funding decision pertaining to an on-going project, whether an initial CBA exists or not.

Of course, when an initial CBA does exist, the analysis in subsequent years is considerably easier. This is so because under my methodology, the initial CBA for an ASW project, incorporating Rapid Prototyping (RP) and anticipating a three year development cycle, would include a decision tree analysis (DTA) of the year-by-year alternative possible milestones of accomplishments and subsequent choices. Such a DTA spells out precisely what to do, once we know which one of the various possible milestones actually occurred during the previous year.

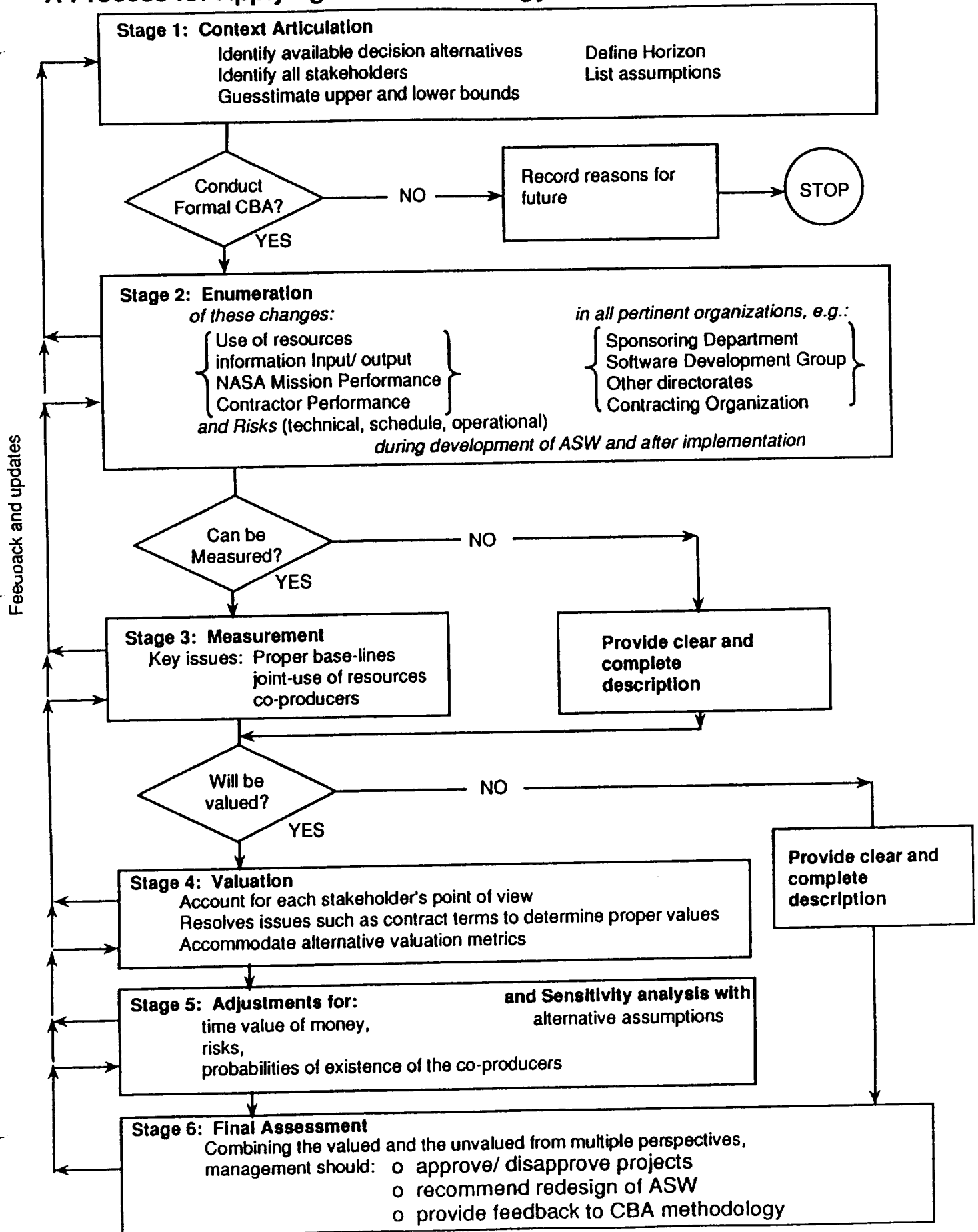
Perhaps the most pervasive misconception of the CBA methodology is that it accounts only for the "economic" costs and benefits, and ignores the many non-economic values we seek. With that misconception, some people even suggest that a CBA has no role to play in any government agency, let alone NASA, since government agencies exist precisely because market forces fail to provide for certain non-economic societal needs. I have shown elsewhere that economists in general, and CBA methodologists in particular, have always concerned themselves with the capture of the non-economic values [1]. The methodology I am proposing insists that all values, economic and non-economic, be captured, and captured explicitly. When this methodology is implemented, perhaps its greatest contribution may lie in the clarification of the real values at KSC, in such trade-offs as between obtaining assured launch success using existing (and proven) technology and developing ASW for more efficient and effective launch operations in the future.

2.3 A Process for Implementation

With this overall framework in mind, I propose that at KSC, we use the six-stage process depicted in Figure 1 for assessing various ASW investment alternatives.

Stage 1 requires that the decision context of a CBA study be articulated explicitly. That is, we must identify the decision alternatives to be evaluated in as specific terms as possible. For example, in the SCAN replatforming project (See Attachment A), evaluating the costs and benefits of the total replatforming effort does not help any decision, since in face of the obsolescence of the current platform, replatforming must be done. What we need is an assessment of the incremental costs and benefits of each enhancement sought while replatforming. We must still assess the costs and benefits of the basic (no enhancements) replatforming effort, but only to set the base-line from which the incremental costs, benefits, and risks of an enhancement can be assessed.

Figure 1
A Process for Applying CBA Methodology to ASW Investment Decisions



In addition, in this **Context Articulation Stage**, we identify all the major stakeholders of an ASW project, define the horizon (one year, or five years, etc.) over which benefits and costs will be assessed, guesstimate the upper and lower bounds on the costs and benefits of each alternative, and make decisions on which alternatives will be the subject formal CBA studies, and from which stakeholders' points of view. In other words, we make a judgment on which CBA studies would be cost-beneficial.

It is important to define a *reasonably long but limited* horizon. For example, it does not help any decision we can make today, if we assess the costs and benefits KATE assuming final completion and implementation of the total KATE vision, which is estimated to need \$27M in software engineers' time alone. At the current funding level of \$300K, it will take ninety years to realize that vision! (See Attachment B).

In the Context Articulation Stage, we should also begin to compile a list of assumptions underlying our study. In subsequent stages, we should be diligent in updating this list, as necessary.

Stage 2 requires the **enumeration** (or listing) of **all the categories of changes** resulting from an investment in an ASW alternative, both during the development of the ASW and after it is operational, but without going beyond the defined horizon. These changes may be in:

- (i) the use of resources including hardware, facilities, labor (both software engineers' time, and supporting experts' time), etc.,
- (ii) information input and output including quantity, quality, speed and timing,
- (iii) NASA's mission performance including on-schedule and safe launches, maximum productive use of available resources, being at the cutting edge of technology and providing commercial spin-offs, etc., and
- (iv) Contractor performance including profitability, productivity, etc.

We want to enumerate these changes not only in the sponsoring department (e.g., a vehicle flow manager in the case of GPSS), and the software development group, but also in the various non-sponsoring but potentially affected directorates and contractors. As suggested before, this may be important in obtaining the necessary cooperation from the experts in various affected organizations, without risking a neglect of their normal duties.

In addition to the above changes, we should also enumerate the technical, schedule and operational risks associated with an ASW project. Also, we should not forget to update the list of assumptions we began to compile in Stage 1. Indeed, as depicted by the feedback arrows in Figure 1, I visualize the six stages of this process to be overlapping, earlier stages requiring feedback and updating from later stages, and vice versa.

In short, Stage 2 ensures that we account for all costs, benefits, and risks of an ASW project, and their timings, within the defined horizon. It also ensures that immeasurable costs, benefits, and risks remain as prominent in our analysis as the

measurable ones. After all, making a decision (in Stage 6) inevitably involves a trade-off between the measured and the unmeasured.

Once the relevant changes are enumerated, it is important to identify those that defy any measurement (e.g., the quality of information), describe them as clearly and completely as possible, and determine if they are still amenable to valuation (perhaps through such approaches as the user's willingness to pay).

When feasible, measurement that occurs in Stage 3 is an important preliminary to valuation. However, even in the case of the measurable, such as the reduction in scheduling meeting durations attributable to GPSS (See Attachment C), we must have a proper historical *base-line* measurement, and the ability to project that base-line into two futures, one with GPSS implemented, and one without. Just because in the pre-GPSS environment, we used to schedule a meeting for an hour, and we used to invite 106 people to this meeting, does not mean we can use 106 hours per day as the base-line. We must examine as to how long these meetings actually used to last, and how many people used to actually attend.

If nothing else, Stage 3 tells us what data we must begin to collect, so as to track the performance improvements brought about by an ASW. In projecting the without-ASW future, it is important to not assume a simple status quo from the history. We must examine as to what other forces may be influencing the base-line. For example, experience in scheduling past Orbiter flows may also help reduce the scheduling meeting durations necessary for future flows.

Similarly, a reduction in weekend overtime, claimed as a benefit of GPSS (See Attachment C) may also be the result of a simple management policy to not approve certain types of overtime work regardless of what it does to the launch schedule, and the result of improved logistics and operations technologies in OPF. What is important is to *isolate and measure the incremental contribution* of GPSS to this reduction in overtime.

It is important in the measurement stage to identify the many co-producers (i.e., necessary conditions) a proposed ASW may need in producing a benefit. For example, to realize the savings in Firing Room manpower afforded by KATE or RUBICON (See Attachments B and D), a co-producer is the necessary cultural and attitudinal change in LCC management. When such co-producers are identified, one must estimate their probabilities of existence during each year of the defined horizon, and then in Stage 5, make the necessary adjustments to the measured or valued annual benefits, by multiplying the benefits with these probabilities. Thus, if the likelihood of a cultural change is zero, the expected benefits of manpower reduction due to KATE and RUBICON will be zero.

Another issue in the measurement of ASW project benefits is whether several projects are claiming the same benefits. For example, both KATE and RUBICON may be claiming the same reductions in the Firing Room manpower.

On the cost-estimation side, a similarly complicating issue is one of the joint use of same resources (e.g., the same computer and communications hardware) by many different projects. We need to develop a systematic method for identifying the incremental changes in these resources brought about by each ASW project.

Costs are often assumed to be easier to measure than benefits. However, in identifying exactly what costs are *incremental*, there are many issues that need to be resolved particularly in the contract management environment at KSC. If contractor compensation is based on head-count, will not the savings in direct labor on one task (brought about by an ASW) be simply "absorbed" (at least, in terms of their accounting) by some other tasks? If demonstrated savings will be accomplished only in future years through prudent contract negotiation, such a contract negotiation should be identified as a co-producer of those savings.

In Stage 3, the idea is to measure the changes in resources in their *physical units*, e.g., labor hours, CPU hours, etc. Then in Stage 4, we attempt an explicit valuation of these resource changes. Of course, we may deliberately exclude some of the resource changes from this valuation. For example, as long as the replatformed SCAN meets the desired maximum access time requirements, we may not place an explicit value on the system's actual access time. On the other hand, certain changes that could not be measured (such as better quality of information) could now be explicitly valued at least in subjective terms by the users of that information. This is possible as long as we do not insist on valuing everything in dollar terms. Thus, at least until Stage 6, some changes may be valued in dollars while others are valued on a "user satisfaction scale" of 1 to 10, etc.

Separation of valuation from measurement is critical in the multi-perspective analysis I am proposing. It allows us to recognize that different stakeholders value a given change in resources very differently. For example, from a cost-plus-fixed-fee contractor's point of view a cost saving has no positive or negative value. For an empire-building manager, the reduction in the manpower under his supervision has a negative value. If a fixed G&A pool will be collected by the contractor by the end of the year, regardless of the direct labor hours involved, should not G&A be left out of the rate NASA uses to value each labor hour saved? The proper labor rates to use in Attachments B, C, and D can be arrived at, only when issues of this sort are resolved.

For many other resources such as computer hardware or office facilities, market prices are commonly seen as an "objective" source of value. However, economists point out that market prices are not value-free; they derive from a particular income distribution and from existing institutional and legal arrangements. As such, at times it is necessary to adjust market prices to reflect specific stakeholders values. For certain benefits, such as the improved quality of decisions supported by an ASW, market prices may not be available and valuation must be imputed from the relevant stakeholder's beliefs, attitudes, and preferences.

Clearly, a number of assumptions are required in this valuation stage, and we must not forget to update our list of explicit assumptions. Sometimes, during valuation we realize that somethings we had originally decided not to measure can and need to be measured. Thus, there may be a feedback from this stage to Stage 3.

In Stage 5, the explicit values must be adjusted for the timing and uncertainty of their occurrence. It is in this **Adjustment Stage** that we must also adjust for the probabilities of existence of the co-producers of our benefits. These adjustments often require assumptions regarding discount rates and the various stakeholders' risk preferences. Thus, once again, we must update our list of assumptions. Finally, in this stage we must also conduct a sensitivity (i.e., what-if) analysis considering alternative values for the various assumptions, e. g., alternative discount rates, alternative timings of occurrence of particular events.

At the conclusion of Stage 5, the analyst's task is complete. In Stage 6, the decision-maker(s) must consider the valued and the unvalued together from each stakeholders point of view to arrive at the final assessment of an ASW alternative. Sometimes this **Final Assessment Stage** may provide a clear decision regarding the funding of the project, and sometimes it may lead to a redesign of the ASW project under consideration to make it more attractive to one or more stakeholders. In the latter case, we may have to repeat the entire process beginning with Stage 1.

2.4 Implementation Requirements and Advantages

From the many analytical issues I have identified, it should be clear that the conduct of this methodology cannot be left to the software engineers of an ASW project. The methodology must be guided by a person who is knowledgeable in the underlying philosophical, economic, and financial principles. This person would need the advice and cooperation of people familiar with contract terms and accounting systems, in addition to the advice and cooperation of the major stakeholders of an ASW project. The first time we apply this methodology, these requirements may seem prohibitively expensive and time consuming. However, once the first full study is complete, the methodology will be easy to apply to other ASW projects since a number of complicated measurement and valuation issues may be already resolved.

I think that an investment in this methodology will pay back many times over through better decision-making at KSC. As suggested in the foregoing discussion, the use of this methodology will also provide the following additional by-products:

- (i) No additional efforts needed to justify the decisions to external bodies,
- (ii) Better product designs of the ASW under consideration,
- (iii) Greater cooperation and commitment to the ASW project from the multiple stakeholders,
- (iv) Greater chance of on-schedule and successful development and implementation,
- and (v) Knowing the co-producers of our ASW's benefits may help us work on improving the probabilities of existence of those co-producers.

3. A Review of the Current CBA Practice at KSC

Before I say anything else, I must say that I appreciate the willingness of the authors of the CBAs in attachments A through D to subject their studies to a methodological review. Given that they had no background or training in the relevant philosophical and economic issues, I admire their creativity and courage in authoring these studies. I mean no harm or insult to these authors when I point out the conceptual errors in their methods. I particularly admire them for recognizing, on their own, that most of their numbers were simply wild guesses, and that the margin of error in their estimates was perhaps very large. I am most encouraged to find that these authors are highly interested in obtaining the necessary background, and in developing a better methodology for the future.

In Section 2, I have already commented on many specific conceptual issues in the studies represented in Attachments A to D. I will be happy to provide additional detailed comments and suggestions to the authors, if they so desire. However, here I want to review the overall practice of CBAs at KSC. In the light of my proposed methodology, we can observe many deficiencies in the current practice. However, two important deficiencies seem to be the root causes of the rest of them.

First, CBAs are not done to actively assist the decisions at hand. Instead, they seem to be produced for public relations (i.e., justification of past decisions), or documentation requirements (in the justification of a preferred decision). In project review meetings I observed, CBAs were often introduced casually with phrases such as "now let us see where we are going with our numbers." In other words, they are given little credibility, and practically no scrutiny.

Indeed, at KSC, I have observed instances where managers facing complex problems deliberately avoided CBAs. I believe that this practice is based on the many misperceptions of what a CBA is, and how it can assist decision-making, discussed earlier. I hope this report helps correct that misperception. At the same time, as I will explain in a minute, given the current state of CBA practice at KSC, these managers were fully justified in avoiding CBAs.

Second, the conduct of CBAs is left to the initiative of software engineers who have little background, training, or assistance in the pertinent methodology. Thus, each study seems ad hoc, developing its own methods and concepts. Indeed one engineer suggested that it was KSC's standard operating procedure "to build a brand new road every time we want to go to Orlando!"

Each one of the available studies seems to violate one or more of the fundamental principles of the CBA methodology. None of the studies I examined tried to capture *all* the costs and benefits, as is required by the methodology. None of them made *all* of their underlying assumptions explicit, or estimate probabilities that the explicit assumptions will be valid. Most studies did not seem to use proper base-lines or proper projection methods in the measurement of their costs and benefits. They failed to separate

measurement from valuation, and to address the many issues of valuation from the perspective of the multiple stakeholders. Even the more commonly understood practices of the CBA methodology, such as adjusting for time value of money in a multi-year stream of costs and benefits, were not used in the CBAs at KSC.

In short, the current practice is seriously deficient.

Speaking as a professor, I am sorry, but I must assign an F grade to this practice. At the same time, I must add that despite this team grade, most individuals who are involved in the current practice of CBAs get unqualified A grades. These individuals have been doing their parts sincerely and to the best of their abilities. They have also been very cooperative and candid with me and open to my ideas. As will be clear below, the deficiencies of the current practice are not the fault of any individual.

3.1 The Vicious Circle

As I think about the two root causes of deficiencies together, I have come to realize that we are caught in a vicious circle which can be described as below:

- Available CBA studies measure only selected (not all) changes brought about by the development and implementation of a given ASW. At times, they force quantification of the non-quantifiable, or prediction of the unpredictable. The baselines used in the measurement are often incorrect. Measurement (in physical units) is not separated from valuation. Valuation is from a single (as against each stakeholder's separate) point of view. Values are not adjusted for their probabilities or timing of occurrence. Sensitivity analysis is not done. In short, many principles of the CBA methodology are violated.

As a result,

- The focus of the CBA studies is primarily on the quantifiable. Very important but non-measurable costs, benefits, and risks are left out. The margin of errors in the quantified estimates is very large. The real values of the Agency mission, the values of senior managers, the values of the contractors, etc., are not captured by the analysis.

Then,

- Because CBA s do not capture and address the real values and issues, and because the studies' estimates are unreliable, Management looks at CBAs not as decision-making tools, but as mere exercises in generating numbers for external justification of decisions already made.

Thus,

- Management allocates few resources, and leaves the conduct of CBAs up to the initiative of the software engineers involved in specific projects.

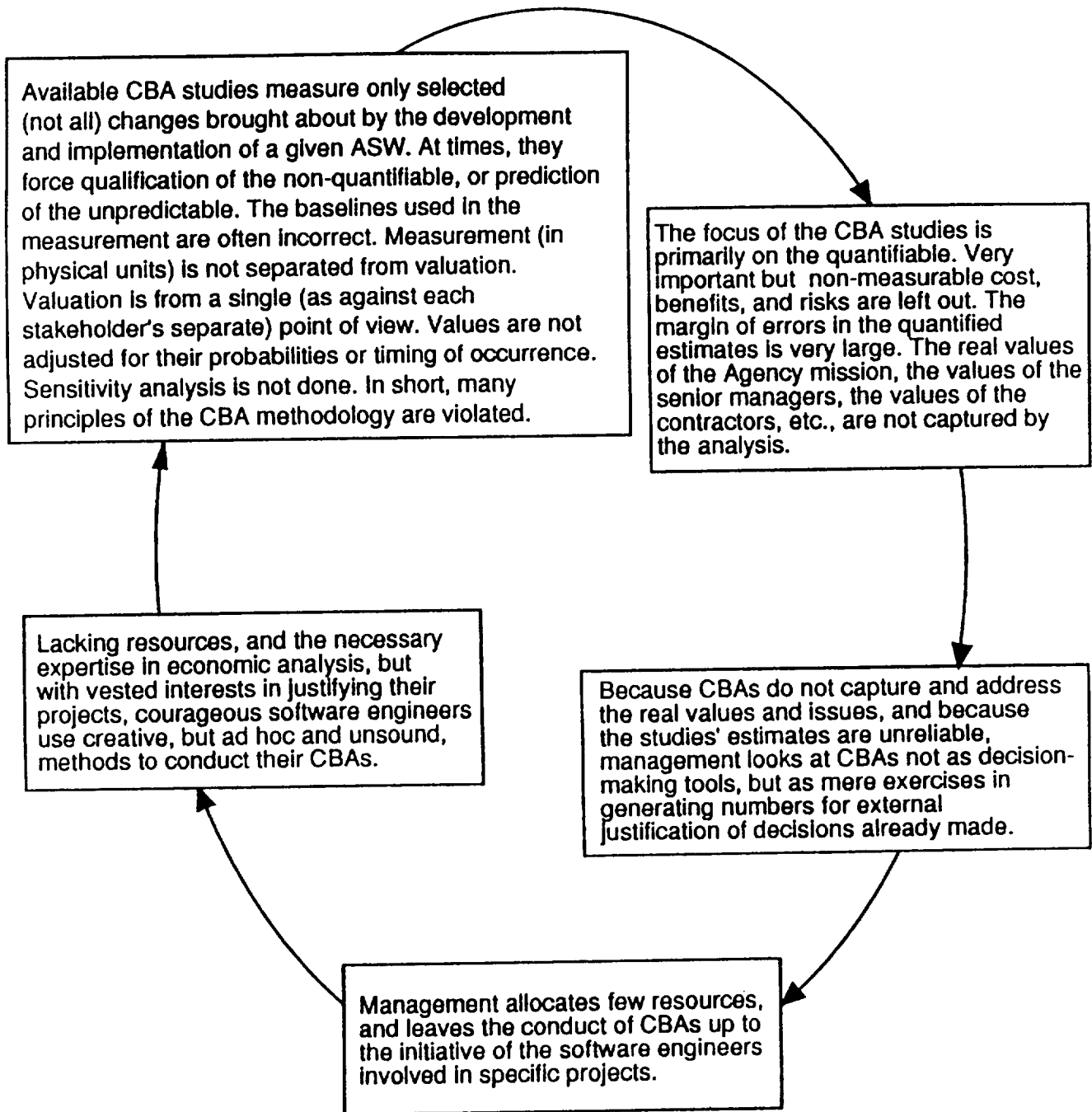
Next,

- Lacking resources, and the necessary expertise in economic analysis, but with vested interests in justifying their projects, courageous software engineers use creative, but ad hoc and unsound, methods to conduct their CBAs.

But this results exactly in the situation described in the starting bullet of this process, and the vicious circle continues!

Figure 2 depicts this vicious circle graphically.

Figure 2.
The Vicious Circle



4. Conclusion and Recommendations

I have argued that ASW investment decisions are multi-stage, varied, complex, risky, and controversial. Therefore, we need a systematic methodology to assist rational ASW investment decisions. I proposed a formal, explicit, and multi-perspective cost-benefit analysis (CBA) methodology for this purpose. I outlined a number of rich concepts and principles of this methodology, and described a six-stage process for its implementation. In the light of this methodology, we reviewed the current practice of CBAs at KSC.

Although I have concluded that current practice is seriously deficient, I believe that most NASA employees already knew that, and many are looking forward to improving that practice. I think my principal contribution is the identification of the vicious circle we are in, and consequently, my primary recommendation is:

Break out of that vicious circle.

The methodology I have proposed provides one exit point to break out of this circle. The other exit point is a change in management's perception of what a good methodology can do, and its willingness to provide adequate resources and appropriate expertise to the conduct of CBAs.

References

1. Toraskar, Kranti, and Joglekar, Prafulla, "Applying Cost-Benefit Analysis (CBA) Methodology for Information Technology Investment Decisions," in R. D. Banker, R. J. Kauffman, and M. A. Mahmood (Eds.): *New Perspectives on the Strategic and Economic Value of Information Technology Investments*, Idea Publishing Group, Middletown PA., December, 1992.
2. Gross, A. M., "Is Cost-benefit Analysis Beneficial? Is Cost-effectiveness analysis effective?" The Heller School for Advanced Studies in Social Welfare, Brandeis University, 1976. Distributed by the National Technical Information Service (NTIS).

Excerpts from a CBA of SCAN Replatforming

5. Costs and Benefits

5.1 Benefits

The benefits for the replatforming of SCAN are difficult to quantify because they are primarily associated with mandated changes to LSDN. The planned migration toward the OSF operating system will make a number of the current SCAN software components (i.e. D3M, Dialog) obsolete which means that replatforming is required. However, with the necessity for replatforming comes the opportunity for a number of significant improvements to the system that will be the main benefits to the user community. The main benefits to be realized by the new system are as follows.

No required resync; engineers will be able to perform useful work immediately after accessing the system. Also, no garbage collection and no checkpoint operations as required by the LISP language.

A single on-line database which will make all data available to the users at all times and elimination of the need to reconstruct a new KB for each mission. Elimination of KB builds will also mean that system engineers will have access to modified circuitry as soon as EO modifications are entered.

Elimination of unused reports and replacement with reports that are more in line with the needs of the user Community.

5.2 Cost Breakdowns

Initial estimates indicate that SCAN replatforming will be an expensive undertaking. There are a number of key issues which must be resolved and the volume of functionality make the replatforming a non-trivial task. The major element of cost will be associated with software development, although some costs will be accrued by implementation as well as revised running costs. Cost estimates are defined in the following sections using CASE Methods estimation tools in conjunction with the best data available at this time.

5.2.1 Development Cost Estimates

The development cost of replatforming SCAN are best understood in terms of the four primary development stages described by CASE Methods. These stages are Analysis, Design, Build and Documentation. Each of these stages are described below with manpower estimates based on the best information available at this time.

The Analysis stage will verify the findings from the Strategy Stage and expand them into sufficient detail to ensure system accuracy, feasibility and a sound foundation for design.

The Design Stage will take the detailed requirements from the Analysis Stage and find the best way to fulfill them and achieve agreed service levels, given the technical environment and previous decisions on required levels of automation.

The Build stage will code and test programs, using appropriate tools. These depend on the technical environment and types of programs involved.

The Documentation Stage will deliver user manuals and operations hand-over documentation, which must be sufficient to support the system testing tasks in the concurrent build stage.

The current manpower estimates associated with the described tasks are as follows (calendar weeks equals total man-weeks divided by 4.2; current manning level).

See APPENDIX A.3 Manpower Analysis Summary, for details.

| | | |
|---------------------|------------------|------------|
| Analysis Stage | Total man-days: | <u>475</u> |
| | Total man-weeks: | <u>95</u> |
| | Calendar weeks: | <u>23</u> |
| Design Stage | Total man-days: | <u>696</u> |
| | Total man-weeks: | <u>139</u> |
| | Calendar weeks: | <u>33</u> |
| Build Stage | Total man-days: | <u>715</u> |
| | Total man-weeks: | <u>143</u> |
| | Calendar weeks: | <u>34</u> |
| Documentation Stage | Total man-days: | <u>18</u> |
| | Total man-weeks: | <u>4</u> |
| | Calendar weeks: | <u>1</u> |

The primary impact of this analysis is an indication that the replatforming may not be achievable per the original schedule at the current manning level. Current manning levels indicate that a February 1994 completion date is a more reasonable estimate. To meet the planned schedule of a July 1993 completion date would require increased manpower as follows:

| Stage | Required Manpower |
|-----------|----------------------|
| Analysis | 5.6 |
| Design | 4.6 |
| Build-Doc | 8.2 |

See Appendix A.4, Proposed Development Schedule and Milestones, for scheduling implications of the estimated manpower requirements.

5.2.2 Implementation Estimates

Implementation estimates will depend on hardware decisions which have not been made at this time. Implementation costs will also be associated with the transition methodology discussed in section 4.3.3.

5.2.3 Running Cost Estimates

Running cost estimates should be reduced significantly because of the elimination of the Knowledge Base build tasks currently performed by Data Bank. Running costs will also be modified by the maintenance level required on any new hardware. Running costs may be increased by additional backup requirements imposed on LSDN, which may be required to reliably support the planned RDBMS.

While all run cost data is not available at this time, it is expected that the replatformed system will present a net decrease in operational running costs.

5.3 Cost/Benefit Analysis

The analysis of costs versus benefits is virtually impossible in the context of SCAN platforming, for a number of reasons. The Replatforming is mandated by software obsolescence, the benefits to be gained are not easily quantifiable and some of the costs are unknown at this time. The best that can be stated is that the replatforming will be expensive as indicated by the estimates in section 5.2.1. To keep these costs in perspective, it must be remembered that it has taken more than five years for the SCAN system to achieve its current level of functionality, including effort associated with approximately 300 Problem Reports. The costs included in these estimates are a recognition that SCAN is still a complex system and they also represent a commitment to field a replatformed system, coded correctly the first time and ready for enhancements that will continue to reduce the System Engineering workload.

Costs Benefits Analysis for the Deployment of the Knowledge Based Autonomous Test Engineer (KATE)

INTRODUCTION

KATE is a tool for health monitoring of electromechanical and fluid systems which is capable of detecting, isolating and diagnosing failure causes. Capabilities exist for automatic correction of failure is , but is currently not deployed for use with Shuttle. Current work includes development of a C++ version of KATE for use by the Firing Room Integration console engineer's Vehicle Health Management System (VHMS).

What follows is a cost benefits analysis for the complete deployment of KATE into the Firing Room environment for both launch and day to day operations. As with all forecasts, several caveats and assumptions were incorporated into this analysis and are stated below. Since the development and deployment of intelligent process control and monitoring systems are in their infancy at KSC much of the cost data needed for a detailed cost benefits analysis either does not exist or is in a format/environment in which it is difficult to obtain. With that stated, this analysis for KATE must be viewed as being, in it's essence, a qualitative and speculative study of costs and benefits of the KATE system. In areas where it was felt sufficient cost data existed quantitative Dollar values were extrapolated from this data. For those areas where insufficient cost data existed a quantitative estimate was derived from plausibility arguments. The derivation of all the cost benefit values have been left outside of the main body of this text and reside as appendices at the end of this report.

ASSUMPTIONS

1. This analysis does not take into account the validation costs for KATE deployment. this is due to the fact that at the present time no decision has been made concerning the methodology to be used in validating non-GOAL, Firing Room resident applications.
2. This analysis does not take into account any transition costs other than estimates for training costs included into assumption # 5.
3. Since at the current time only one Shuttle system has been implemented in KATE (KATE-LOX) a linear extrapolation of costs is estimated for an expansion in the economy of scale from one application to a firing room wide system.
4. A measure of modelling complexity for a Particular Shuttle system is defined as the number of Function Designators (FDs) associated with that system.
5. A measure of model development time is given as 8 hr/FD. This assumption is based on experience and assumes a KATE neophyte programmer (i.e. this includes the time necessary to learn and model in KATE).
6. The labor rate is defined as 40.00 \$/hr, (approximate LSOC rate).

SUMMARY OF ANALYSIS

IMMEDIATE BENEFITS (< 3 yrs)

1. KATE can draw conclusions on system behavior, both current and future, based on analysis of measurement input. Upon operational activation, for the integration console alone savings of @ \$ 150,000 per vehicle per flow may be realized due to three less support engineers being required for daily monitoring operations (non-active testing). This figure is based on 3 on-station engineers working 3 shifts per day at 60 days per flow. Total cost savings, based on six flows per year, would equate to \$ 900,000 per year.

POTENTIAL BENEFITS (>3 yrs)

2. KATE represents one analytical tool which can be used for multiple subsystems by changing the knowledge base used for reasoning and analysis. Cost savings are in reduced system development time since only the knowledge base for each class of system needs to be developed. Life cycle cost savings are in sustaining engineering, since the same reasoning software is used for all subsystems.

2.1 Estimated Cost Expenditures

The costs in developing a total KATE Firing Room system (including knowledge bases for each Shuttle system as well as the KATE shell) is estimated to be @ \$ 30 Million.

Note that the capabilities currently residing in GOAL pertain only to control and monitoring capabilities, whereas KATE would have these with the addition of diagnostic capabilities.

2.2 Estimated Cost Savings

Sustaining engineering costs for a fully deployed KATE system, on a per year basis are estimated to be @ \$ 5.67 Million.

Note that this sustaining engineering cost estimate is approximately less than the estimated costs for sustaining the current complement of GOAL software (see appendix). The KATE sustaining engineering cost savings for maintaining ground software that may be realized are estimated to be @ \$ 2.33 Million .

Further cost savings are realized by allowing a reduction in the amount of Shuttle system engineering labor required to perform day-to-day Shuttle monitoring and maintenance operations. Following other cost benefit studies done concerning advisory systems (see appendix B) a 13 % reduction in man-power may be realizable without impairing safety. This savings equates to approximately a savings of \$ 5.62 Million per year.

The total costs savings that may be realized on a yearly basis is estimated to be
@ \$ 7.95 Million per year.

Other Benefits

3. The same KATE/system version can be used for real time data analysis or as a simulation tool for training and off-line system evaluation. Costs savings are realized by deleting the necessity of maintaining separate software for operations and training activities as is currently done.
4. Reduction in the size of launch team for all other consoles based on the same rationale as used in #1 & #2.2 above.

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX A

| CONSOLE | FD | 8 hr/1d | RATE | COST/CONSOLE |
|---------|--------|----------------------|---------------|--------------|
| C2 | 8000 | 64,000 hrs | @ 40.00 \$/hr | \$ 2.56 M |
| C3 | 5600 | 44,800 | — | 1.79 M |
| C4 | 5600 | 44,800 | — | 1.79 M |
| C5 | 2400 | 19,200 | — | 0.77 M |
| C6 | 6500 | 52,000 | — | 2.08 M |
| C7 | 5100 | 40,800 | — | 1.63 M |
| C8 | 5900 | 47,200 | — | 1.89 M |
| C9 | 6400 | 51,200 | — | 2.05 M |
| C10 | 4200 | 33,600 | — | 1.72 M |
| INTG | 2000 | 16,000 | — | 0.64 M |
| C11 | 7000 | 112,000 ¹ | — | 4.48 M |
| C12 | 10,000 | 160,000 ¹ | — | 6.40 M |
| TOTAL | | | | \$ 27.80 M |

ESTIMATED COSTS FOR KNOWLEDGE BASE DEVELOPMENT

1. This estimate was doubled to take into account the uncertainty in developing KATE applications involving high-speed digital systems.

| CONSOLE | FD | SIZE |
|---------|--------------------------------------|--------------|
| | 8000 X 10 LINES C++ FD | 80,000 LINES |
| C2 | 5600 | 56,000 |
| C3 | 5600 | 56,000 |
| C4 | 2400 | 24,000 |
| C5 | 6500 | 65,000 |
| C6 | 5100 | 51,000 |
| C7 | 5900 | 59,000 |
| C8 | 6400 | 64,000 |
| C9 | 4200 | 42,000 |
| C10 | 2000 | 20,000 |
| INTG | 7000 | 70,000 |
| C11 | 10,000 | 100,000 |
| C12 | | |
| TOTAL | 68,700 | 4,081 K |

KATE with control : Estimates based on experience with the KATE-ALO system suggest a 15 % increase in the amount of code needed to realize control procedures. :

$$4,081 \text{ K} + 15 \% = 4,693 \text{ K lines}$$

ESTIMATED SIZE OF TOTAL KATE C++ APPLICATION

SUSTAINING ENGINEERING

GOAL ESTIMATES

7 MILLION LINES OF GOAL CODE (@)

100 S/W ENGINEERS (@)

LSOC LABOR RATE = 40 \$/hr

ONE MAN YEAR = 2000 hr

SUSTAINING ENGINEERING COSTS ESTIMATE = 2000 hrs X 40 \$/hr X 100 = \$ 8,000,000 \$/Yr

$\frac{8,000,000 \$}{7,000,000 \text{ lines}} = 1.143 \$/\text{line}$

KATE ESTIMATE

4,963,000 lines X 1.143 \$/line = 5,670,000 \$/Yr

POTENTIAL NET SAVINGS

8,000,000 \$/YR - 5,670,000 \$/YR = 2,330,000 \$/YR

Excerpts from a CBA of GPSS

COST SAVINGS

1. The daily scheduling meetings were considerably shortened. If the daily scheduling meeting would have been held using the non-AI schedule, approximately 83 hours of meeting time would have been expended for the entire flow. However, because of the use of the AI based scheduler, only 42.03 hours were spent, yielding a savings of about 40.23 hours. Based on a rate of \$34/hr for each of the 106 engineers that attend the meetings, the use of the GPSS schedule resulted in a savings of about \$144,988 (See attachment 1) for the engineers' time along with a savings of about \$12,000 for the person who used to physically "lay tape" for the paper schedules.

2. Reduction/elimination of weekend overtime. Weekend overtime is expensive but often necessary to prevent even more costly delays. TPS (Thermal Protection Systems) technicians utilized the GPSS scheduler to predict required overtime during this flow based on vehicle configuration. Normally during a 16 week flow TPS spent \$481,950 on overtime. By utilizing the GPSS scheduler \$110,129 was actually spent for technician support. This results in a cost savings of \$371,821 (See attachment 2). The savings was accrued because GPSS was able to predict weekend overtime and reduce or eliminate in some instances due to better forecasting of conflicts.

Total cost savings for STS-50, OV-102 are estimated at \$528,809.

RUBICON COST ANALYSIS STUDY

I. TASK DESCRIPTION

Evaluate the RUBICON concept from all aspects to determine if the continued development and subsequent implementation into CCMS 2 as well as the office environment will provide a cost pay back for shuttle operations.

II. ASSUMPTIONS

A. RUBICON development will continue in the direction described below.

- o The DLES displays and code will be used as the RUBICON DPS system monitor. LCC resolution, MDT, DEU dump analyzer and other analysis applications will run under the system monitor.

The following items are planned for implementation in FY93:

- o DLES must be modified to allow multiple applications to run on the same machine and then will become RUBICON.
- o The MDT CLIPS portion will be incorporated to run under this new RUBICON system.
- o Where feasible, the software developed by Rockwell will be utilized (ex. WPA keystrokes).
- o RUBICON must be converted to run under MOTIF.

Future plans/capabilities will depend on the direction system engineering decides to best suit testing needs.

- B. The management issues for allowing vehicle monitoring from a remote location (outside the Firing Room) will be worked.
- C. The transmission of data from all 4 vehicles on a single network will be completed and validated. This is currently scheduled to be complete around the mid-1993 timeframe.
- D. The ethernet network used for the transmission of vehicle data and workstation to workstation communication will be fully maintained and supported.

ORIGINAL PAGE IS
OF POOR QUALITY

RUBICON COST ANALYSIS STUDY

III. POSITIVE COST SAVINGS

A. Optimization of manpower resources

Description: RUBICON can be used either in the office or in one PR to monitor all 4 vehicles during times of vehicle power-up MONITOR ONLY support. It is estimated that DPS is in a monitor only mode approximately 85% of the time the vehicle is powered up.

Est Savings: \$274,000 (4 eng x \$33/hr x 40 hr/wk x 52 wks).
DPS currently supports vehicle power up periods 3 shifts a day with 4 engineers on first shift, 4 on second shift and 2 on third shift for a total of up to 10 people a day. RUBICON can be utilized as a method for survivability by DPS hardware engineers to continue vehicle support when shuttle budget cutbacks impact the number of system engineers in the group. The number of engineers supporting vehicle testing could be reduced to 2 people per shift for a total of 6 people a day without impacting vehicle testing.

B. Avoid opening unnecessary IPR's

Description: Anomalous conditions that have been seen before and documented on an IPR can happen again at a later date. With no IPR/PR history data readily available, IPR's can be opened only to be researched long enough to find out that the problem was seen before and is an explained condition. The engineer must then close the IPR as an explained condition.

Est Savings: \$18,000/yr
There has been an average of approximately 16 explained condition IPR's opened per year (averaged over the last 12 years). It is estimated that out of those 16 IPR's that RUBICON could have potentially avoided approximately 9. These problems were either addressed on previous IPR's or the data in the RUBICON database could have helped understand the problem and avoid opening an IPR. The estimated cost to open and close an IPR is \$2,000 (This figure does not include the time required to investigate the problem).

C. Potential avoidance of an unnecessary launch scrub

Description: If the time remaining in the launch window is short, by providing a quick, precise explanation or work-around procedure for an LCC violation (one that can

ORIGINAL COPY IS
OF POOR QUALITY

be rationalized as being OK to launch given certain conditions are met) that would allow the count to resume quickly you could preclude an unnecessary launch scrub.

Est Savings: A minimum \$1 million savings would be realized.

D. Tradeoff between GOAL versus RUBICON maintenance for DPS System display monitoring.

Description: Once RUBICON is incorporated into C12 application software in CCMS 2, approximately 12 GOAL display programs will no longer be required. Thus, the maintenance manpower required on the GOAL software can be redirected to maintain the RUBICON system monitor software.

Est Savings: No cost savings but no additional cost incurred.

E. Improved training for new hires

Description: When new hires are brought on board they currently must go through extensive training. With the record and playback and debugger capabilities, engineers can be trained using actual vehicle data to get an understanding of how the DPS system works. Failures can also be inserted to test reactions to problems. This capability is supported totally separate from the CCMS set thus avoiding scheduling conflicts and reducing the impact on other systems.

On the software development side, most computer related degrees require C as a programming language. New hires can be more productive in a much shorter timeframe.

Est Savings: Savings is hard to determine but has the potential be a significant amount.

N/

F. Office/Firing Room tool to reduce the time it takes to find historical information.

Description: IPR/PR historical data and the PMW must often be researched to support anything from general management questions/concerns to troubleshooting problems. By searching a quick access database for the required information you can reduce the manpower required to provide the necessary information.

Est Savings: \$13,000/year
Estimated 15 system engineers spending .5 hours per

week searching documents that reside in the RUBICON database. The time required to search the PNW on a specific topic for example can be reduced by as much as 20 minutes.

0. "Path finder" for new approaches and capabilities for CCMS 2.

Description: New approaches to monitoring and analysis can be tested and evaluated. If more efficient techniques can be developed and proven in this environment they could be utilized faster and easier in the CCMS 2 environment. Conversely, techniques that are tested but do not work can be noted and the same mistakes could be avoided in the CCMS 2 environment.

Est Savings: CCMS 2 will require a massive learning curve. A side benefit of this and other similar projects will be a faster understanding of new approaches to system health monitoring.

1. "Path finder" for new approaches and capabilities for future launch vehicles.

Description: New approaches to monitoring and analysis can be tested and evaluated. If more efficient techniques can be developed and proven in this environment they could be utilized faster and easier in a future launch vehicle environment. Conversely, techniques that are tested but do not work can be noted thus repeating the same mistakes could be avoided in the new environment.

Est Savings: Future launch vehicles will require a significant learning curve. A side benefit of this and other similar projects will be a faster understanding of new approaches to system health monitoring utilizing "state of the art" hardware/software. Portable software modules can be reused with some minor modifications, greatly reducing software development time/costs.

ORIGINAL PAGE IS
OF POOR QUALITY

RUBICON COST ANALYSIS STUDY

IV. NEGATIVE COST SAVINGS

A. Dual maintenance of GOAL displays and RUBICON System Monitor.

Description: During the timeframe from October 1993 until CCMS 2 is operational, there will be maintenance required on both the GOAL software as well as the System monitor portion of RUBICON.

Cost Impact: \$4,500/year
Will require approximately 50% manhour increase on mandatory design center change packages. There were 26 mandatory change drivers (that impacted the 12 GOAL display programs that DLES can replace) over the past 2 years for a total of approximately 550 manhours. This figure does not include the LCC monitor.

B. Additional maintenance required to maintain CLIPS rules.

Description: An additional .5 engineer would be required to maintain the expert system portion. (Note: This includes maintenance on the LCC, MDT and any other CLIPS module.)

Cost Impact: \$35,000/year
Cost is more than absorbed in the reduction of the number of system engineers required.

C. Additional maintenance required for database.

Description: There will be a small increase in manpower required to maintain the database. However, automation routines will make this task a simple procedure. Database routines can be run while other tasks are performed.

Cost Impact: \$2,100/year (8 flows/year x 8 hr/flow x \$33/hr)
It will take an estimated 8 hours per flow to maintain the database. With documents on line there would be less need to manually update the paper version of the documents. A reduction in document distribution can also be realized as well as reducing the amount of paper used.

D. Additional work required to set up additional CM tracking procedures.

Description: The initial development of rules/guidelines will be a minimal impact and is already in work. This would be a one time impact that could (like all other processes) require periodic modification.

Cost Impact: No RUBICON cost impact. The operational impact is unknown but should not require a significant amount of additional work. (Note: This task will be done for other systems that are being developed anyway.)

E. Office hardware maintenance costs.

Description: The UNIX machines utilized to run RUBICON outside of the CCMS 2 environment would require maintenance from time to time.

Cost Impact: Exact cost is not known at this time. The actual dollar amount will be insignificant since there is a large scale maintenance contract on the Apollo's. To date, no repair costs have been incurred (this covers a period of approximately 2 years). Plans are in work to fold the maintenance of these workstations under the LSDN maintenance plan. This will provide quick turnaround on hardware problems. Exact cost is not known at this time.

F. CLIPS validation.

Description: The validation of the CLIPS portion of RUBICON is under review. No data exists on this at this time.

Cost Impact: Exact cost is not known at this time.

ORIGINAL PAGE IS
OF POOR QUALITY

